Energy Transition with focus on CO2 & H2 Pipelines

COPEX 2022 – Session 1
October 19th 2022

Wim Guijt
Principal Technical Expert Pipelines

1

COPEX 2022 Session 1 – Industrial Challenges Long-Term Mega trends Energy Transition with focus on CO2 and H2 Pipelines

Agenda

- CO2 Pipelines
  - Current CO2 transport experience
  - Shell participation CCS Projects & FEED Studies
  - Key topics for CO2 transport
  - Earlier EU CO2 Network Development Studies
- H2 Pipelines
  - Role of H2 in future Energy system
  - Integrated Energy Chemical Parks - Industrial Hubs
  - Current H2 transport experience
  - Shell H2 Project involvement and R&D
  - Key topics for H2 transport
  - Recent EU H2 Network Development Study

2

CO2 Pipelines

1

3

Existing onshore CO2 pipeline systems in USA

2016: 4,565 miles (7,345 km)

U.S. regions with large-scale CO_2 pipeline systems currently in operation	Miles of Pipeline
Permian Basin *(W. TX, NM, and S. CO)*	2,320
Rocky Mountains *(N.CO, WY and MT)*	810
Gulf Coast *(MS, LA, and ETX)*	740
Mid-Continent *(OK and KS)*	480
Other *(ND, MI, Canada)*	215

139 Number of U.S. CO_2-EOR Projects
- Natural CO_2 Source
- Industrial CO_2 Source
- CO_2 Pipeline
- CO_2 Proposed Pipeline
- CO_2-EOR Region

2020 US PHMSA data for CO2 pipelines:
- 5,150 miles (8,300 km) – all dense phase
- 13% increase over the last decade

Source: U.S. Department of Energy, "Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure," April 2015.

4

CO2 Pipeline Transport: Onshore (US EOR) & Offshore

523 km 24" Green Pipeline, Denbury (2010)

808 km 30" Shell Cortez Pipeline (1983)
12 mtpa - 650 MMscfd initial capacity

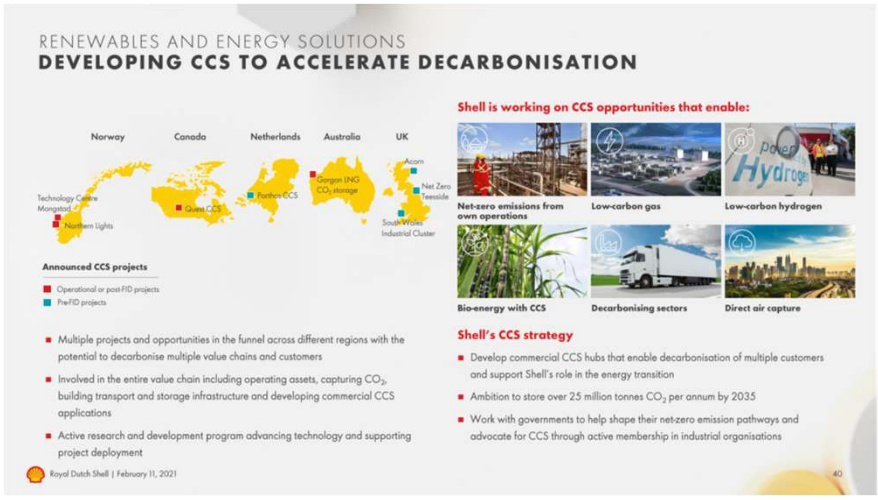
Now Operated by Kinder Morgan, current Capacity 28 mtpa – 1,500MMscfd

Offshore CO2 Pipeline Transport:
a <u>single</u> pipeline to date

153 km 8" Snøvhit pipeline, Equinor/Statoil (2005)
Operational April 2008, Capacity 700 ktpa

5

Shell CCS Projects and Strategy
Store 25 mtpa CO2 by 2035 & net-zero-emissions by 2050



Reduce Shell and industry emissions through CCS

- Invest in CCS in North West-Europe through a portfolio of projects in the UK, Norway and the Netherlands
- Northern Lights project under construction in Norway. Stores up to 1.5 million tonnes of CO_2 per annum
- Invest in CCS to unlock low-carbon blue hydrogen production for industrial decarbonisation

6

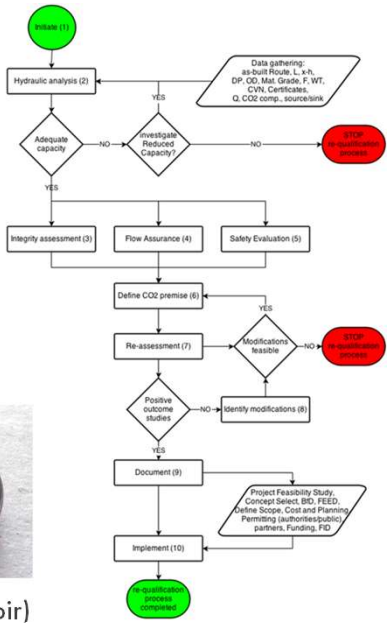
Shell participation CO2 transport Projects & FEED Studies

- Projects
  - Shell Quest CCS Project in Canada
    - FID taken in 2012, Start CO2 injection 24-08-2015 (5 mtpa stored in nearly 5 years by July 2020)
    - Main line 65 km 12" (150 barg), having a design capacity of 1.2 mtpa
  - Gorgon LNG (Shell interest 25%)
    - off the coast of Western Australia, Barrow Island, start injection August 2019 (5 mtpa stored on 19 July 2021)
    - the world's largest CCS Project up to 4.0 mtpa
    - CO2 captured from produced gas, transported by a 7.3 km 12" pipeline
  - JV Project involvement: Northern Lights (Norway), Porthos & Aramis (Netherlands), NEP & Acorn (UK)
- Previous UK FEED studies & various JIP involvement (2010 – 2014/2015)
  - UK CCS Longannet (FEED completed), no FID taken (cost)
  - Peterhead (FEED completed), no FID taken (cost)
    - Re-use of an existing 20" offshore pipeline (and platform/wells) – now again part of Acorn

7

Key topics for CO2 pipelines

- Impact of Impurities (CO2 stream composition/specification)
  - Water solubility, dehydration requirements, corrosion & acids
  - Equation of State, fluid properties, modelling
- Material selection (Typically Carbon Steel)
  - Line Pipe toughness (Running Ductile Fracture, RDF)
  - Non-metallics (soft seals)
- Pipeline Operations & Maintenance
  - Flow Assurance: Pipeline depressurisation (low Temperature due to phase change)
  - ILI Pigging (velocity, distance, wear, non-metallic materials)
- Pipeline Requalification (constraints!)
  - Capacity (design pressure – offshore/onshore), Availability (timing)
  - Line Pipe toughness – RDF, material certificates
  - Integrity status, modifications, valve replacement
  - QRA (Dispersion, Safety) for onshore pipeline, facilities
- System Integration (capture, compression, pipeline, well/injection, reservoir)



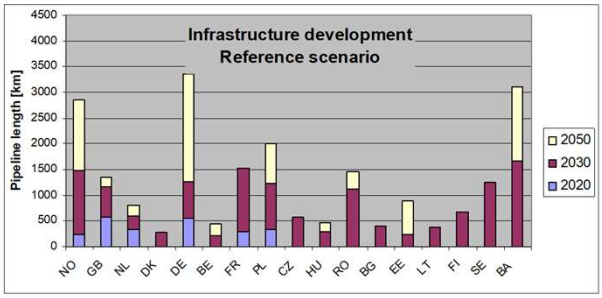
8

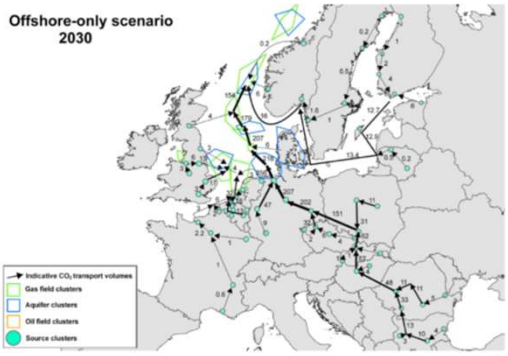
CO2 Network development (2011)

- Captured CO2 (mtpa) 2020: 40, 2030: 400, 2050: 1200
- 2050 CO2 network comparable to EU Oil/Products system
- Construction effort ~ 500 - 1,500 km/year
- Key findings consistent with studies JRC (2011), ARUP (2010)

CO2Europipe

	Total trunk line length [km]		
	Reference scenario	Offshore-only scenario	EOR scenario
2020	2.300	4.200	5.300
2030	15.000	20.000	21.000
2050	22.000	33.000	33.000





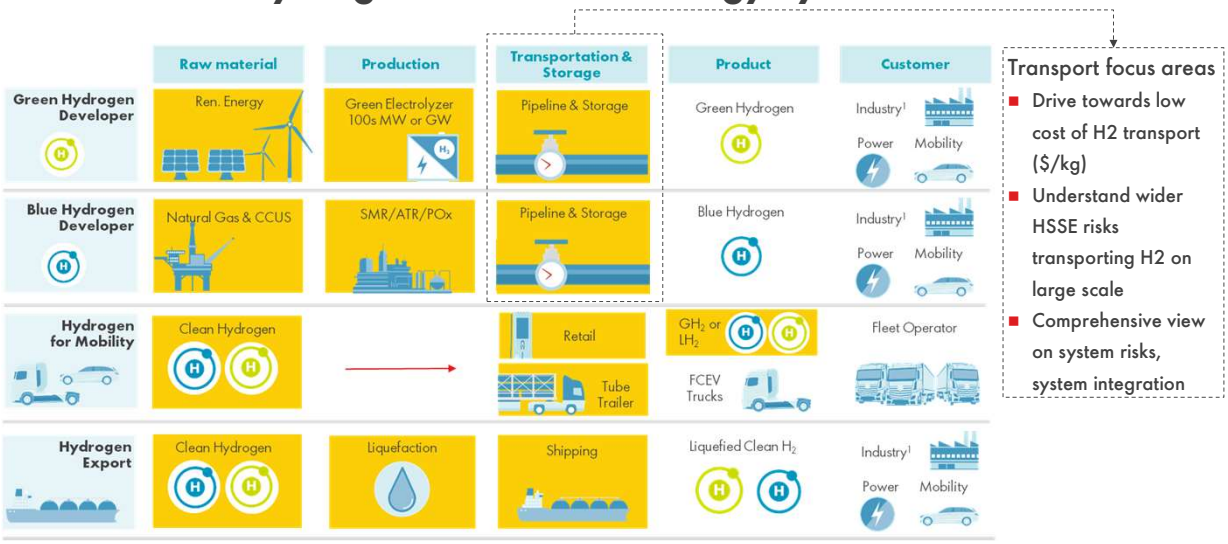
9

H2 Pipelines

2

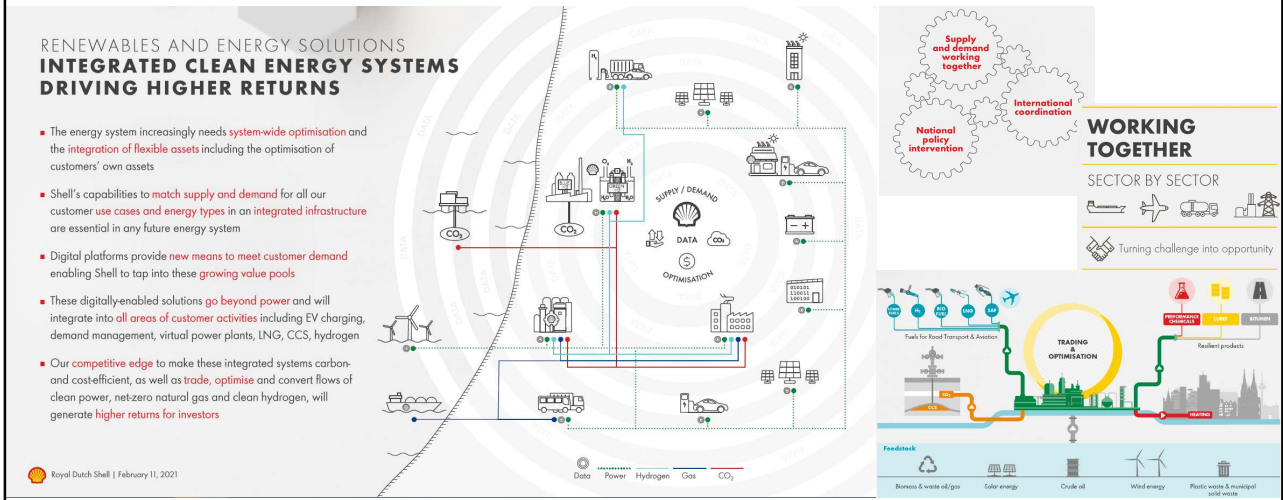
10

Overview of Hydrogen in the Future Energy System



11

Integrated Energy & Chemical Parks - Industrial Hubs



12

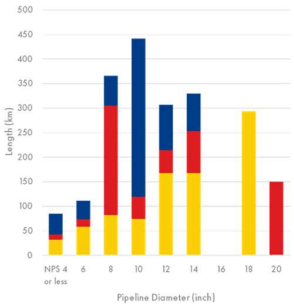
Existing H2 Pipeline networks

Main Industrial Areas of:

- USA Texas/Louisiana
- Germany (Ruhr area), since 1940s
- Rotterdam (NL)/Antwerp (BE)/Northern France

Company (2016)	km
Air Liquide	1,940
Air Products	1,140
Linde (incl. Praxair)	980
Others	480
World Total	4,540

Continent (2016)	km
US	2,610
Europe	1,600
Rest of World	340
World total	4,540



2019 PHMSA Data US For 3 main H2 Pipeline Operators (2,100 km)

https://h2tools.org/hyarc/hydrogen-data/hydrogen-pipelines (2016)

2020 PHMSA Data US All H2 Pipeline Operators 2,500 km, increase of 14% since 2010 (2,200 km)

13

Shell H2 Projects and R&D involvement

Electrolyzer Projects - Operational:

- Germany – Refhyne, 10 MW (July 2021)
- China – Zhangjiakou City, 20 MW (January 2022)
  - Phase 2 plans to scale up to 60 MW in next 2 years

Ongoing Studies:

Refhyne II (Germany)

- 100 MW Electrolyser and SAF project

Green Hydrogen Hub (Netherlands)

- Green Hydrogen plant Tweede Maasvlakte, Port of Rotterdam
- The hydrogen plant will have a capacity of around 200 MW

NortH2 Feasibility Study (Netherlands)

- Gasunie, Groningen Seaports, Shell, Equinor and RWE
- ambition to grow to about 10 GW around 2040

AquaVentus (Germany) – 90 parties

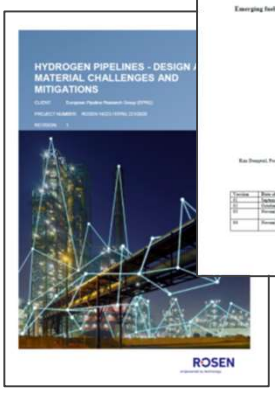
- ambition to grow to about 10 GW around 2035

NortH2

AquaVentus

Internal & External H2 R&D

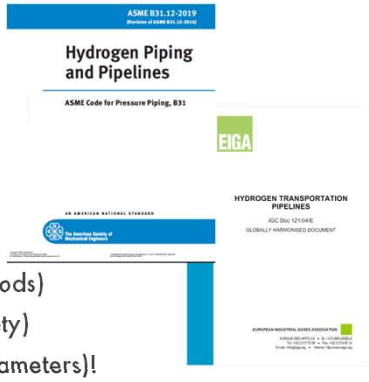
- EPRG
- PRCI/EFI



14

Key Topics for H2 Transport

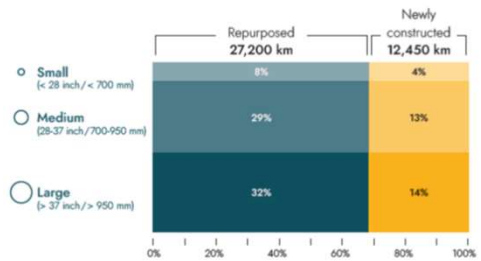
- H2 properties and specifications (purity and contaminants, blending and comparison with methane)
- Design of H2 pipelines (Codes & Standards, EoS, Capacity/Sizing, impact impurities)
- Capacity (Energy) / Buffering H2 pipelines & Storage (Δp – pressure fluctuations, fatigue)
- Material selection (low-grade Carbon Steel, non-metallics - permeation)
  - CS Material Grade & sour service (strength, ductility, toughness)
  - Fracture control (fatigue crack growth): Low Grades & Low Stress level
- Re-use of existing infrastructure, conversion gas pipelines
  - blending H2 with Natural Gas or near pure H2 (timing/availability)
  - integrity status (pipe & welds), fatigue crack growth (defects)
- Construction and commissioning (welding: hardness requirements)
- Operational aspects (compression, inspection, leak detection, repair methods)
- Operational safety aspects of H2 pipelines (permeation, QRA/Public Safety)
- System integration & envisaged scale enlargement (both in Length and Diameters)!



15

H2 Network development (European Backbone 2040)

from https://gasforclimate2050.eu/wp-content/uploads/2021/06/European-Hydrogen-Backbone_April-2021_V3.pdf



		Low	Medium	High
Pipeline cost	€ billion	33	41	51
Compression cost	€ billion	10	15	30
Total investment cost	**€ billion**	**43**	**56**	**81**
OPEX (excluding electricity)	€ billion/year	0.8	1.1	1.8
Electricity costs	€ billion/year	0.9	1.1	2.0
Total OPEX	**€ billion/year**	**1.7**	**2.2**	**3.8**

16

Questions and Answers

Q&A

17

18